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NASA TECHNICAL TRANSLATION NASA TT F-15,476

INVESTIGATION OF THE EFFECT OF CERTAIN ELEMENTS ON THE HIGH-TEMPERATURE STRENGTH OF ALUMINUM-TITANIUM (Ti_3Al)

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(NASA-TT-F-15476) INVESTIGATION OF THE EFFECT OF CERTAIN ELEMENTS ON THE HIGH-TEMPERATURE STRENGTH OF ALUMINUM-TITANIUM (Ti3Al) (Kanner (Leo) Associates) 9 p CSCL 11F G3/17 N74-31002 Unclas 45887

Translation of "Issledovaniye vliyaniya nekotorykh elementov na zharoprochnost' alyuminida titana Ti_3Al," Novyy konstruktsionnyy material -- Titan (A New Construction Material -- Titanium), Edited by I.I. Kornilov and N.G. Boriskina, Moscow, "Nauka" Press, 1972, pp. 101-104

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 AUGUST 1974

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TT F-15,476		
4. Title and Subtitle INVESTIGATION OF THE EFFECT OF CERTAIN ELEMENTS ON THE HIGH-TEMPERATURE STRENGTH OF ALUMINUM-TITANIUM (Ti_3Al)		5. Report Date August 1974 6. Performing Organization Code
7. Author(s) O.N. Andreyev and I.I. Kornilov		8. Performing Organization Report No. 10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates, P.O. Box 5187 Redwood City, California 94063		11. Contract or Grant No. NASw-2481 13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes
Translation of "Issledovaniye vliyaniya nekotorykh elementov na zharoprochnost' alyuminida titana Ti_3Al," Novyy konstruktsionnyy material -- Titan (A New Construction Material -- Titanium), Edited by I.I. Kornilov and N.G. Boriskina, Moscow, "Nauka" Press, 1972, pp. 101-104

16. Abstract
Elements from groups IV-VIII and IVB were used to examine the heat resistance of aluminum-titanium, when alloyed with them. It was found that when alloyed with vanadium or molybdenum, Ti_3Al is more easily deformed at high temperatures. The great heat resistance of the alloy at 750° and a stress of 25 kgf/mm^2 occurs when alloyed with 1 technical atmosphere-% of W, Sn, Mo, Hf, Si, Zr, Tr, Nb, V.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	9	

NASA-HQ

INVESTIGATION OF THE EFFECT OF CERTAIN ELEMENTS ON THE HIGH-TEMPERATURE STRENGTH OF ALUMINUM-TITANIUM (Ti_3Al)

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According to the physicochemical theory of heat resistance, intermetallic semiconductors can be the basis of heat-resisting alloys [1]. In the Ti-Al system a number of metallic semiconductors are formed: Ti_3Al, TiAl, $TiAl_3$ [2, 3]. From this series of compounds aluminum-titanium Ti_3Al has a very high heat resistance with a satisfactory technological plasticity at high temperatures [4]. /101*

In this work, a study was made of the effect of 1 technical atmosphere-% of transient metals IV-VIII and elements IVB of groups of a periodic system for the heat resistance of the Ti_3Al compound. From the IV group of metals, the following were chosen: Zr and Hf; V - V, Nb and Ta; VI - Cr, Mo and W; VII- Mn; VIII - Fe, Co and Ni; from elements of IVB group - C, Si, Ge, Sn and Pb.

Initial materials and research methods into alloys. The Ti_3Al compound was melted by a double melting method. Pure metals were used as alloying elements: zirconium and hafnium iodide, vanadium, niobium, tantalum, molybdenum, armco iron from an electron beam melt; electrolytic chromium, manganese, nickel, tin, cobalt; tungsten was introduced in the form of a Ti-W alloying element (25 wt-% W); lead, in the form of a Ti-Pb alloying element (16 wt-% Pb); carbon, in the form of a Ti-C alloying element (4 wt-% C); extremely pure silicon and germanium. Ingots weighing 500 grams were melted in a vacuum arc furnace with a nonconsumable tungsten electrode in an argon atmosphere.

The alloys were melted five times to guarantee the uniform

*Numbers in the margin indicate pagination in the foreign text.

distribution of elements. The chemical composition of the alloys was checked by relative weighing of the blend and ingot; the difference did not exceed 0.2-0.5%. The extracted ingots were cut into three sections and forged in a temperature interval of 1300-1100° into rods with a diameter of 8 mm. Alloys in this temperature range deform satisfactorily as β-solid solutions, with the exception of alloys containing germanium and silicon.

Alloys with a Ti_3Al base, alloyed by vanadium and molybdenum, had the greatest plasticity during deformation. The alloy specimens forged into rods underwent the following thermal treatment: 1000°, 100 hours; 800°, 100 hours; 500°, 300 hours, with subsequent slow furnace cooling to room temperature. Annealing was done in double evacuated quartz ampules, the residual pressure during welding in the ampules was $5 \cdot 10^{-4}$ mmHg.

Apart from studying the heat resistance, the microstructure of the alloys was studied after annealing (Fig. 1). The Ti_3Al compound has a uniform structure (Fig. 1, a). The heat resistance of alloys was studied by a centrifugal bending method [1, 5] at 750° and a stress of 25 kgf/mm^2. It was determined according to the time required to reach a given deflection, which was shown in work [1], and characterizes most accurately the relative heat resistance of the alloys examined. The Ti_3Al compound, alloyed by zirconium or hafnium, has a polyhedral structure of the α_2 solid phase on the base of this intermetallic compound. Figure 2 shows the creep curves of the alloys examined. It follows from Fig. 2, a that the alloying of Zr or Hf considerably increases the heat resistance of Ti_3Al compound, and hafnium, to a greater extent than zirconium. Whereas the time taken to reach the bending indicator of 10 mm for Ti_3Al was 3 hours, for an alloy with Zr, it was 11 hours, and for an alloy with Hf, 25 hours. Therefore, this shows that Zr and Hf increase the heat resistance of the Ti_3Al compound.

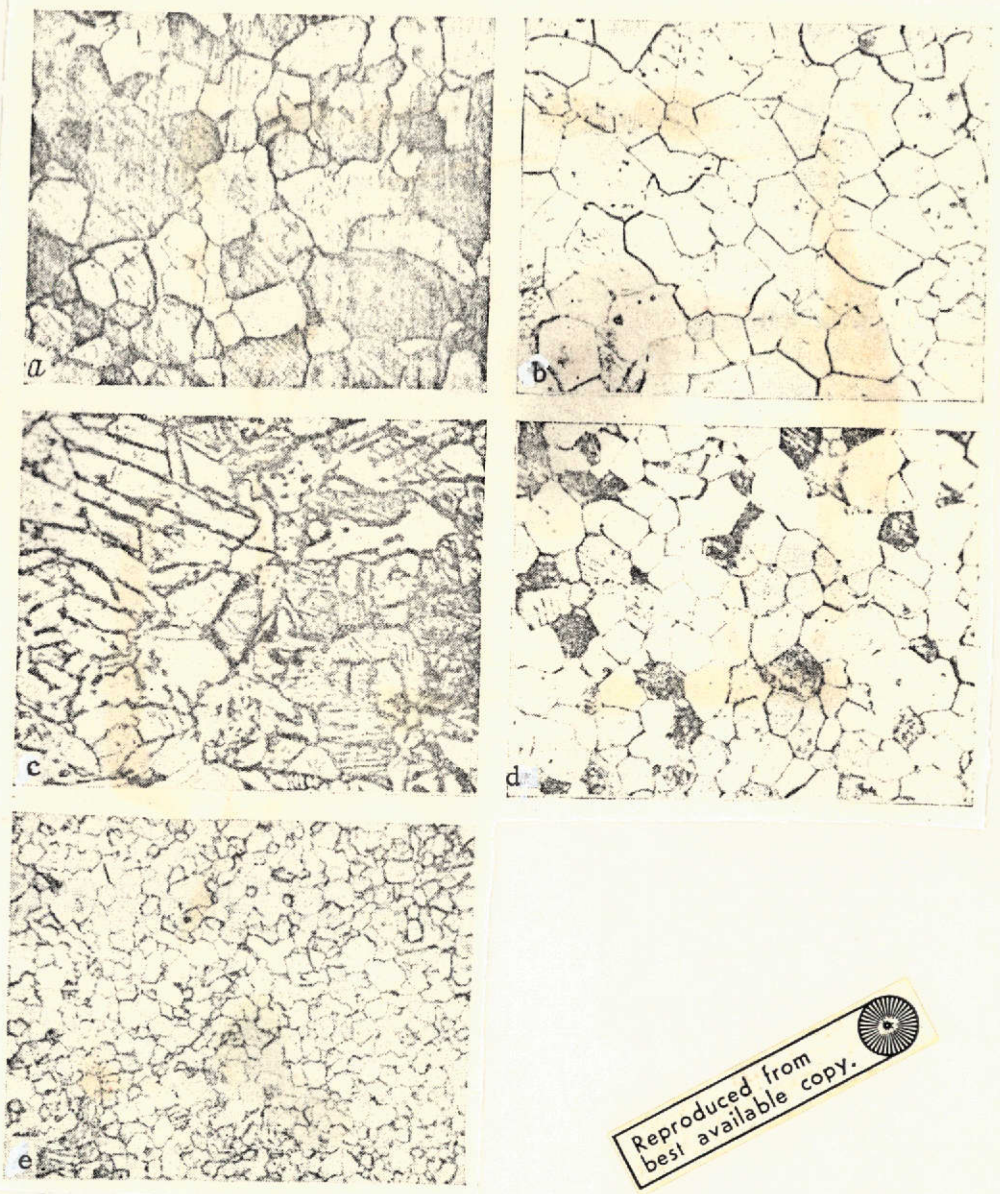

Fig. 1. The microstructure of annealed alloys, 200x. a - initial aluminum-titanium Ti_3Al; b - alloyed 1 technical atmosphere-% V; c - the same, 1 technical atmosphere-% Mo; d - the same, 1 technical atmosphere-% Fe; e - the same, 1 technical atmosphere-% Sn.

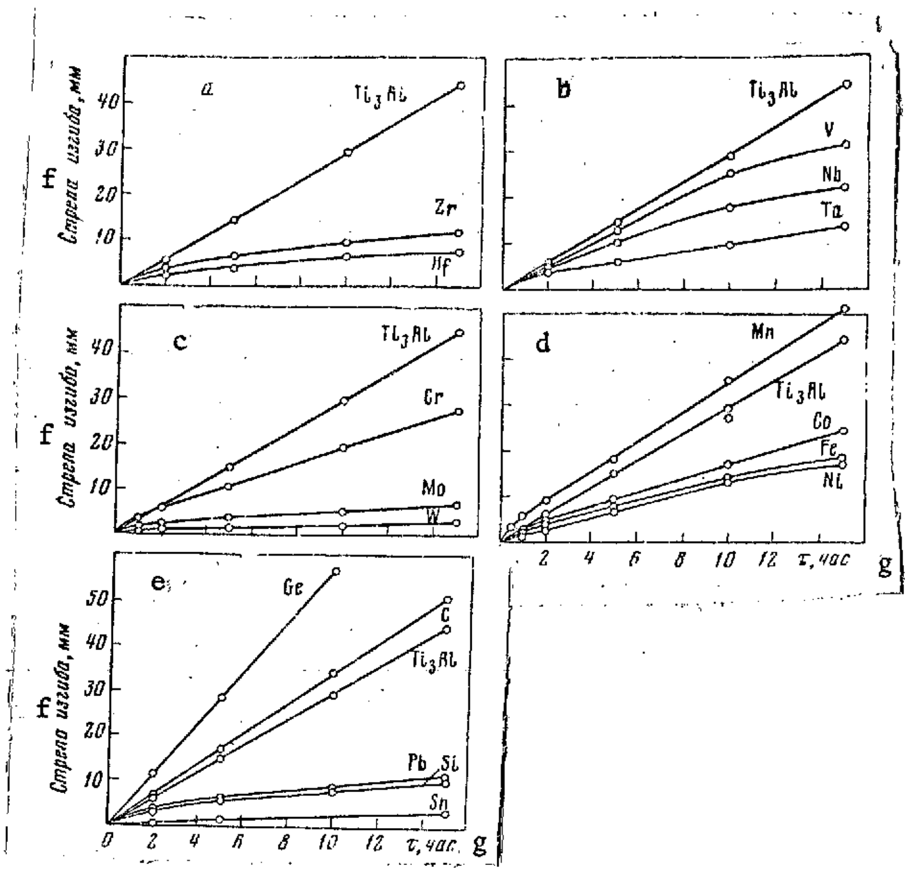

Fig. 2. Creep curves at 750° and σ = 25 kgf/mm^2 of aluminum-titanium Ti_3Al, alloyed at 1 technical atmosphere-%: Zr, Hf (a); Ta, Nb, V (b); W, Mo, Cr (c); Ni, Fe, Co, Mn (d); and Sn, Si, Pb, C, Ge (e).

Key: f. Bending indicator, mm
g. Hours

The microstructure of aluminum-titanium with 1 technical atmosphere-% V or Nb, Ta, Cr is also single-phase, polyhedral (Fig. 1, b), and for an alloy with 1 technical atmosphere-% Mo (Fig. 1, c), it is two-phase. The change in the heat resistance of the Ti_3Al compound, depending on 1 technical atmosphere-% of the alloyed component V, Nb, Ta, Cr, Mo and W is shown in the form of creep curves in Fig. 2, b, c. The creep curves show that aluminum-titanium Ti_3Al is more heat resistant when alloyed with tantalum than niobium and vanadium (Fig. 2, b). Of the metals of the VI group which increase the heat resistance are /102 tungsten, then molybdenum, and finally chromium (Fig. 2, c). These laws of the effect of alloying in the heat resistance of alloys are confirmed by the time taken for the bending indicator to show 10 mm. The bending indicator reached 10 mm for the Ti_3Al compound, as was said earlier, in 3 hours; an alloy with vanadium, 4 hours, with niobium, in 5 hours, with tantalum, in 10 hours; alloys with metal from the VI group are: with /103 chromium, 4 hours, with molybdenum, 25 hours, with tungsten, 100 hours of deformation.[1]

The microstructure of the Ti_3Al alloy with 1 technical atmosphere-% Mn or Fe (Fig. 1, d) is polyhedral, and alloys with cobalt and nickel have a two-phase microstructure. The creep curves of these alloys are shown in Fig. 2, d. From them, it follows that from this series of alloys the most heat resistant are aluminum-titanium alloyed with Ni, then Fe and Co. Alloying with manganese also increases the creep rate of the Ti_3Al compound. The time taken for the bending indicator to reach 10 mm is: for the Ti_3Al compound, alloyed with manganese -- 2 hours, with nickel -- 7 hours, with iron -- 6 hours, and with cobalt -- 5 hours. When the Ti_3Al compound is alloyed with elements of the VIII group, the greatest heat resistance was shown by the alloy alloyed with nickel.

The microstructure of an alloy containing 1 technical atmosphere-% Si or Ge, Sn, Pb, is polyhedral (Fig. 1, e), the microstructure of an alloy with 1 technical atmosphere-% of C is two-phase. A comparison of the bending time of Ti_3Al, alloyed with the elements shown above of IVB group (Fig. 2, e), makes it possible to arrange the alloys in ascending values of heat resistance in the following order: aluminum-titanium, alloyed with tin, then silicon and lead. Carbon and germanium are

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[1]The time taken for the bending indicator to reach 10 mm for alloys with tungsten and tin was determined by extrapolation, assuming a uniform creep rate.

elements which do not increase the heat resistance of the Ti_3Al aluminum-titanium.

These uniformities are confirmed by the time taken for these alloys to reach the bending indicator of 10 mm. The time taken to reach the bending indicator at 10 mm by the Ti_3Al compound, alloyed with tin, was 65 hours; with silicon, 15 hours; with lead, 13 hours; with carbon, 3 hours; and with germanium, only approximately 2 hours.

Conclusions /104

1. The change of heat resistance of the Ti_3Al compound was investigated by the centrifugal bending method, depending on alloying it with one technical atmosphere-% of elements of IV-VIII and IVB groups of the periodic system: Zr, Hf, V. Nb. Ta, Cr, Mo, W, Mn, Fe, Co, Ni, C, Si, Ge, Sn, Pb. It was found that the heat resistance is greater when increasing the series number of the element inside each group.

2. Alloying Ti_3Al with vanadium or molybdenum considerably increases the deformability of alloys at high temperatures.

3. Alloys with an aluminum-titanium Ti_3Al base, alloyed with 1 technical atmosphere-% of W, Sn, Mo, Hf, Si, Zr, Ta, Nb, V have the greatest resistance to heat at 750° and a stress of 25 kgf/mm^2.

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